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A Wave Tracer

Electrical Engineering

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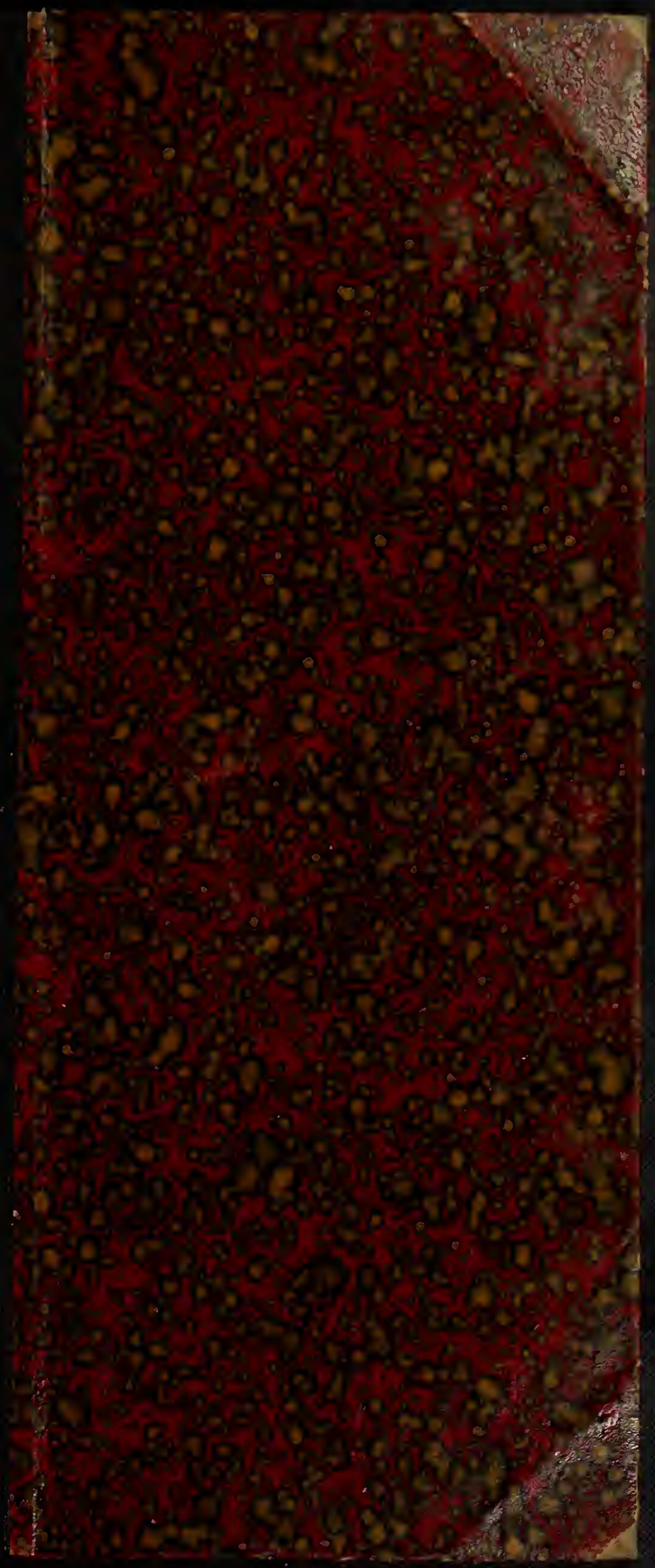

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Class 1911 Book M14 Volume

A WAVE TRACER

BY

ISHMAEL WORTH McDOWELL

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS
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May 31 1901

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Ishmael Wort McDowell

ENTITLED A Wave Tracer

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

H. F. Hake

Instructor in Charge

APPROVED: Ernst J. Berg

HEAD OF DEPARTMENT OF Electrical Engineering

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Introduction

An offer was made in October 1910 to any one in the Senior class to construct a machine which would mechanically demonstrate the phenomena of alternating current and electromotive force waves. It was with this object in view that this work was begun.

Necessarily a piece of apparatus of this kind should be compact, easy to operate and have other facilities which would make it desirable for class room

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demonstration.

The construction was begun according to a design made by H. A. Brown of the class of 'yy.

Theory and Design

If a pin fits into a slide, the slide being held by guides as shown below in the figure

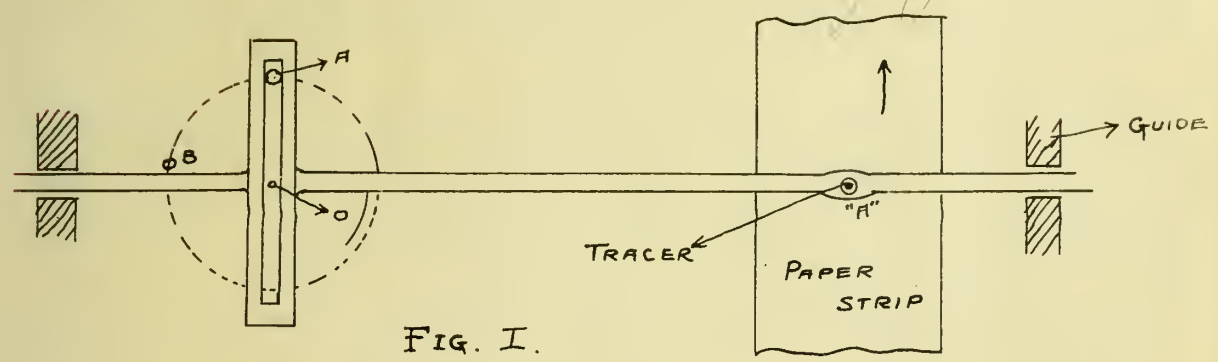

FIG. I.

and if the pin move so that its motion has a component parallel to the guides, then the slide will move a certain amount along the guides. Now it is known that if the pin moves in a circle any point on the slide will have a simple harmonic motion with reference to the path of the pin.

This phenomenan is familiar to any one who has studied the laws of motion in Physics. Imagine a pencil point on the slide rod at "A" and imagine a strip of paper moving across this tracing point at right angles to the motion of the slide. Then if the pin is moved around the circumference of the circle the tracing pencil "A" will trace a sine wave, such as we are familiar with in alternating currents, upon the moving paper. From this the proper conception of an alternating wave of electromotive force or current can be easily obtained, namely that a harmonically varying electromotive

or current cannot be represented by a vector but by a curve which is traced by the simple harmonic motion of ordinates and time as the abscissa. Then we would say that the vectors which are used in alternating current work, such as for diagrams, are simply the radii of the pins which revolve in circles to produce the simple harmonic motion which represents the oscillating value of electromotive force or current. If we imagine another pin at B working in its own slide and always remaining 90° around the circumference from A then the tracing points, each on a different slide, would trace

two waves 45° apart and the radii drawn from the center of motion to A and B would be vectors representing the relative instantaneous values of the two waves and their phase relation. If these two waves represented electromotive forces of two alternators connected in series then the total electromotive force wave would be represented by the vector sum of the two waves A and B. This would also be a sine wave. We can add waves A and B mechanically by connecting pins A and B with arms of the same length as the radii and join the ends of these arms

at C, as shown in Figure II.

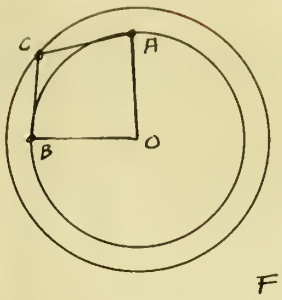

FIG. II.

Now if a pin was inserted at C and another guide and tracer provided for this pin, this tracer would trace a wave which would be the resultant of the two waves A and B. Then the three tracers A, B and C would trace the two components and the resultant wave on the moving paper.

This discussion presumed that both pins A and B revolved in the same direction at the same rate of speed and had the same radii. But suppose now that B.

is nearer to the center than A, that is the vector of B is shorter than that of A and suppose that B moved faster than A, say B made three revolutions while A made one, B would then be the vector representing a third harmonic of A. The resultant wave of A and B would be a distorted wave. Three waves can be made to add mechanically, also, and trace the distorted wave. This point was the difficult one in constructing the machine. In case the two vectors rotate at different rates of speed it is seen that the arms AC and BC will also rotate. But when they move a certain angle

they will form a toggle joint and the motion of C from this position will not be in any way controlled

As was before mentioned, in the rotation of A and B when the speeds of both are the same, the angle x remains constant. Suppose a pulley is fastened to the arm OB at C, and another fastened to arm AC at A and a belt placed around these pulleys. Now if OA and OB are rotated at equal speeds, the pulley on C will turn in the direction of rotation of OA and OB, but the pulley at A will revolve backwards an equal amount, and x will always remain constant. But when OB is rotated two or three times as fast

as O; the angle a will not remain constant but as a matter of fact the arm AC will rotate at the same rate as OO, so what really occurs is the harmonic vector rotating around the end of the fundamental vector. With the belt on the pulleys and a pin, slide and tracer provided for the point C, the resultant of these two rotating vectors, mentioned above, will be traced on the sliding paper.

This is the fundamental principle of the machine, and experiments on the partly finished machine showed that the third tracer did actually add the two components and trace a distorted wave that

is the approximate sum of the two components. Of course the machine did not add the two waves mechanically as we could do with a pair of dividers but it is close enough for demonstration purposes.

The appearance of the fundamental triple harmonic and resultant is shown as follows:

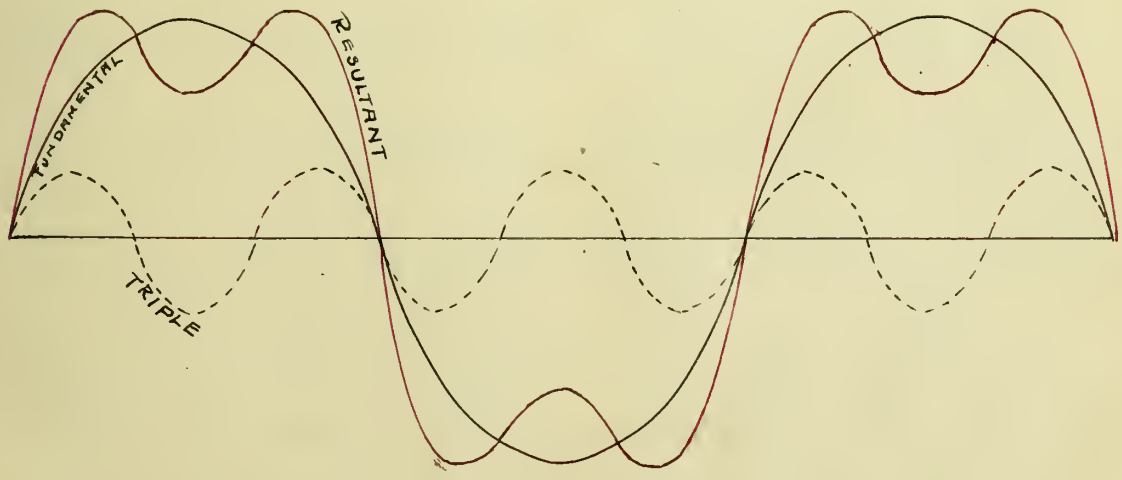

FIG. III

In the machine constructed a few modifications of this design were made. Instead of having two pulleys one at O and one at A, a train of three gears was put in between O and A. one gear at O, another at A and and idle gear between with its axle fixed on the arm OA. This eliminates errors due to the belt slipping. The vector arms OA and OB rotate on the same centers so provision must be made for turning the two arms on the same axle. The different speeds of the vector arms were obtained by connecting the axle of arm OB to that of OA thru a 1 to 3 reducing gear and pinion, and turning OB by mans

of an attached crank which will cause OA to turn one-third as fast.

Theoretically the tracing points should all move in the same straight line and in the same plane. It is impossible in the work constructed to do this, but they were set to just pass each other. This throws them about 1/16 of an inch out of line, but did not seem to affect the accuracy of the machine much.

Instead of having a paper, slide along, a paper disk may be substituted and the tracer will then trace the well known polar diagram originated by Dr. Steinmetz. If the paper disk is used it must rotate with the same

speed as the fundamental, while the sliding paper may be moved at any speed depending on the length of wave desired

The machine was so constructed that the phase relation of OA and OB at any point could be changed, simply by loosening a set screw and turning OB a certain desired amount, while OA stands still. Arms AC and OB were made so that their lengths were adjustable. Arms AC and OB should always be equal. The length of AO and BC were also made adjustable so that the amplitude of the fundamental can also be changed. OA and BC should also

be kept equal.

The following photographs show the machine which was near completion at the end of the year. The slides move vertical, the tracers being fastened to the rods in front of the strip of paper in middle of picture.

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